CHAPTER

1

OVERVIEW OF INTEGRATED SITE DESIGN

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1.1 Purpose and Scope of the Technical Guidance Manual

The Storm Water Manual for the City of Wichita and Sedgwick County consists of three volumes:

- Volume 1 – Policy Manual
- Volume 2 – Technical Guidance Manual
- Volume 3 – Plan Preparation Guidance Manual

Volume 1 is an overview of the general storm water policies that form much of the basis for the storm water and floodplain ordinances, and the criteria and guidelines presented in Volume 2 and Volume 3. Volume 3 is intended to assist the developer and the developer's designers in the plan preparation, review and approval process. The purpose of this Manual (Volume 2 - Technical Guidance Manual) is to provide guidelines and certain criteria to be used in the design and maintenance of storm water management facilities constructed for new developments or redevelopments. These guidelines are intended to be consistent with the storm water policies adopted by the City of Wichita and Sedgwick County, and the storm water and floodplain ordinances. Where inconsistencies occur between the Manual and the policies or ordinances, the latter shall apply.

The Technical Guidance Manual provides guidance on the Integrated Site Design (ISD) methodology whereby the need to control both the water quality and water quantity impacts of new development are incorporated into a comprehensive, coordinated plan for the development site. Included are specific structural and non-structural controls or practices that may be used to accomplish those requirements. In addition, basic guidelines and criteria for the design of storm water management infrastructure are included.

The "case for" integrated site design is presented in Volume 1 and is not repeated here.

1.2 Integrated Site Design

1.2.1 Goals

The basic goals of **integrated site design** for storm water management facilities for new development or redevelopment, as defined in the relevant ordinances, are:

- To the maximum extent practicable, remove pollutants from the storm water runoff from the development to protect water quality;
- Prevent increases in long-term downstream stream bank and channel erosion due to the development;
- Safely convey floods through the project storm water control system;
- Safely pass floods through the downstream project boundary and control facilities without increasing peak flow rates at the project boundary; and,

- Prevent any increase in flooding downstream of the development boundary.

The ISD approach is a coordinated set of design standards used to design storm water controls to address these goals. Each of the ISD design steps may be used in conjunction with the other steps in the process to, in aggregate, address the overall storm water impacts from a development site. When used as a set, the ISD approach addresses a wide range of hydrologic events, from the smallest runoff-producing rainfalls up to the 100-year, 24-hour rain event.

The requirements for achieving the ISD goals are presented in Table 1-1 as steps in the ISD process. Please note that there are some limited exceptions to these requirements. Those exceptions are presented in the ordinances and/or in the detailed discussions of the requirements.

Table 1-1 Steps for Integrated Site Design

Steps	Approach
Step 1: Water Quality Protection	The Water Quality Protection Volume (WQ_v) is the volume of runoff from the development as a result of the 85th percentile rain event. In the Wichita and Sedgwick County area, this is the 1.2 inch rain event. Water quality protection must be achieved by treating the WQ_v to remove 80% of the total suspended solids from the development site runoff.
Step 2: Channel Protection	The Channel Protection Volume (CP_v) is the volume of temporary detention required to detain the development site runoff for the 1-year, 24-hour rain event (of 2.8") for a minimum of 24 hours (centroid-to-centroid) to prevent increased long-term downstream channel erosion. Alternatively, the difference in pre- and post-development runoff for the 1-year, 24-hour rain event may be retained on-site and released through evapotranspiration and/or infiltration, or reused.
Step 3: On-Site Storm Water Conveyance	On-site conveyances must be designed to convey their applicable design rain events (found in Chapter 5) through the project while providing adequate protection from flooding for structures and other critical areas in the development for the 100-year rain event.
Step 4: Flood Protection	Principal and emergency storm water controls must be designed to ensure that the post-development peak discharges for the 2-year through 100-year, 24-hour rain events do not exceed pre-development values at the project boundary, and can be discharged safely from the project.
Step 5: Downstream Assessment	In conjunction with Step 4, principal and emergency storm water controls must be designed to ensure that the post-development peak discharges for the 2-year through 100-year, 24-hour rain events do not exceed pre-development values downstream of the project boundary.

Figure 1-1 conceptually illustrates the relative volume requirements of each of the integrated site design steps and demonstrates that the requirements typically overlay one another. If the assessments for flood control (i.e., steps 4 and 5) indicate on-site detention is needed to limit the discharge from a development, the volume requirement to achieve the flood control requirement could also contain the volume needed to provide for channel protection and water quality protection. The appropriate type of detention facility could be designed with outlet controls to address each of the steps of the design approach. Obviously, detention may not be required in all situations; consideration of site design practices and storm water controls that work together to meet all the requirements is what is important. The following sections describe the integrated site design approach in more detail.

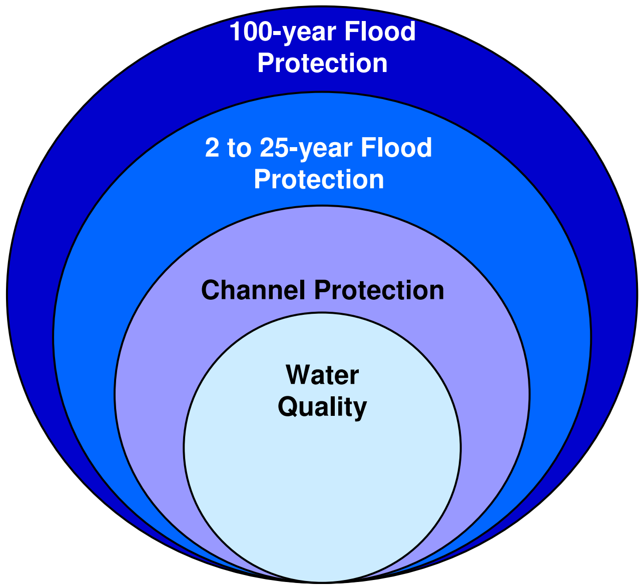

Figure 1-1 Representation of the Integrated Site Design Approach

1.2.2 Water Quality Protection Volume

Hydrologic studies show smaller, frequently occurring rain events account for the majority of rain events. Consequently, the runoff from the many smaller events also accounts for a major portion of the annual pollutant loadings. By treating these frequently-occurring, smaller rain events and the initial portion of the storm water runoff from larger events, it is possible to effectively mitigate the water quality impacts from a developed area.

Studies have shown the 85th percentile rain event (i.e., the storm event that is equal or greater than 85% of the events that occur) is a reasonable target for addressing the majority of smaller, pollutant-laden runoff events. Based on a rainfall analysis, 1.2 inches of rainfall has been identified as the depth corresponding to the 85th percentile storm for the City of Wichita and Sedgwick County (using a 6-hour dry interval to separate "events"). The runoff from these 1.2 inches of rainfall is referred to as the WQ_v. Thus, a storm water management system designed for the WQ_v will treat the runoff from all rain events of 1.2 inches or less, as well as a portion of the runoff for larger storm events.

WQ_v calculations are discussed in detail in Chapter 4 of Volume 2. A brief overview is provided below.

WQ_v is computed using the following equation for small storm hydrology:

Equation 1-1 $$WQ_v = \frac{PR_vA}{12}$$

where:

WQ_v	=	Water Quality Protection Volume (in acre-feet)
P	=	85th percentile storm event (1.2 inches)
R_v	=	ratio of runoff volume to rainfall volume for small rain events (dimensionless)
A	=	drainage area after adjusting for any applicable WQ_v reductions (acres), see section 1.3

- R_v: R_v depends largely on the fraction of the site that is impervious. It also depends on the texture of the soil (i.e., sandy versus clayey) and whether or not the soil has been disturbed. If more than one category of runoff area is present, an area-weighted value of R_v should be used in the WQ_v calculation. See Chapter 4 of Volume 2.
- Multiple Drainage Areas: When a development project contains or is divided into multiple outfalls, WQ_v should be calculated and addressed separately for each outfall.
- Multiple WQ_v Storage Facilities within a Site: See Chapter 3 of Volume 2 for procedures on computing overall treatment for the project when the treatment facilities are de-centralized on the site.
- WQ_v Reductions: The use of certain "preferred site design" practices allows the WQ_v to be reduced. These volume reduction methods are described in Chapter 2 of Volume 2.
- Determining the Peak Discharge for the Water Quality Storm: When designing off-line stormwater management facilities, the peak discharge of the water quality storm (Q_{wq}) can be estimated using the method provided in Chapter 4 of Volume 2.
- Treatment of the WQ_v with a Wet Pool: A wet pool is a detention pond or wetland with a permanent pool. The volume of the permanent pool may be used as treatment for either 50% or 100% of the WQ_v. See Chapter 4 of Volume 2.
- Treatment of the WQ_v by Extended Detention: Either 50% or 100% of the WQ_v may be treated in a detention pond by detaining that portion of the WQ_v for a minimum of 24 hours. For example, if 50% of the WQ_v is held in a permanent pool, then the remaining 50% would be treated by extended detention through temporary storage above the permanent pool. Or, if there is no permanent pool, 100% of the WQ_v would be treated by extended detention through temporary storage in the normally dry pond. The release of water from the extended detention storage is normally controlled by an orifice. See Chapter 4 of Volume 2.
- Determining Extended Detention Time: For extended detention applications, detention time must be estimated to ensure that the 24-hour minimum is satisfied. Since inflow and outflow hydrographs for small storms are not readily predicted, a simplified method is used to estimate detention time. See Chapter 4 of Volume 2 for detailed procedures for achieving the required detention time.
- Control Orifices: Clogging protection must be provided on all orifices. See Chapter 5 of Volume 2 for detailed information about the design of orifices.

Total suspended solids (TSS) is the parameter chosen as the representative storm water pollutant for measuring treatment effectiveness for several reasons:

- The standard of using TSS as an “indicator” pollutant is well established;
- Suspended sediment and turbidity are directly associated with TSS and are a major source of water quality impairment due to urban development; and,
- A fraction of many other pollutants of concern are removed either along with TSS, or at rates proportional to the TSS removal.

1.2.3 Channel Protection Volume

The increase in the frequency and duration of bankfull flow conditions in stream channels (typically the 1 to 2-year storm events) due to development is a primary cause of accelerated channel erosion and the widening and down-cutting of stream channels. Therefore, the channel protection requirements apply to all development sites for which there is an increase in flow from the 1 to 2-year rainfall events (either volume or rate) to downstream channels, ditches and streams. (This type of channel protection is not to be confused with localized protection against erosion and scour. This type of protection is intended to address long-term channel-forming flows associated with stream geomorphological changes. Localized erosion and scour protection is discussed in Chapter 5 of Volume 2.)

Channel protection is achieved by providing 24 hours of extended detention on-site for the post-developed runoff generated by the 1-year, 24-hour rainfall event. The reduction in the frequency and duration of bankfull flows through the controlled release provided by extended detention of the CP_v will reduce the bank scour rate and severity.

An alternative to extended detention of the CP_v is to retain the difference between the 1-year, 24-hour pre-development and post-development runoff volume on-site, and release the volume through evapotranspiration, reuse, and/or infiltration.

Chapter 4 of Volume 2 presents detailed procedures for determining CP_v and for obtaining the required detention. The following is a brief overview.

- <u>Inflow Hydrograph Generation:</u> The hydrograph methods described in Chapter 4 of Volume 2 shall be used to compute the runoff hydrograph for the 1-year, 24-hour storm event, unless the simplified method discussed in Chapter 4 of Volume 2 is used.
- <u>Routing of the Inflow Hydrograph through Storage Features:</u> The modified Puls method described in Chapter 4 of Volume 2 shall be used to hydrologically route the inflow hydrograph through the applicable storage feature, unless the simplified method is used.
- <u>Determination of Extended Detention Time:</u> Extended detention time must be estimated to ensure that it meets the 24-hour minimum requirement. Extended detention time is equal to the time lapse between the centroid of the inflow hydrograph and the centroid of the outflow hydrograph. The centroid times may be determined directly with approved proprietary hydrology programs, or determined by an analysis of the inflow and outflow

hydrographs. When the simplified method is used, the required detention time is accomplished by using the procedures provided in Chapter 4 of Volume 2.

- Multiple Drainage Areas: When a development project contains or is divided into multiple outfalls, CP_v shall be calculated and addressed separately for each outfall.
- Multiple CP_v Storage Facilities within a Site: See Chapter 4 of Volume 2 for requirements on designing overall CP_v for the project when the facilities are de-centralized on the site.
- Routing/Storage Requirements: The required storage volume for the CP_v must lie above the permanent pool elevation in storm water ponds and wetlands. When applicable, the portion of the WQ_v above the permanent pool (extended WQ_v detention) may be included when routing the CP_v.
- Control Orifices and Weirs: Clogging protection must be provided on all orifices. See Chapter 5 of Volume 2 for a discussion of orifice and weir analysis and design.

1.2.4 On-Site Conveyance

On-site conveyances must be designed to convey the applicable design storm event to provide protection for structures, streets, sidewalks, and other critical areas in the development. On-site conveyance is typically accomplished with a combination of conveyance systems including street and roadway gutters, inlets and drains, storm sewers, culverts, swales and ditches. The presence of other storm water management facilities may affect the design of these systems. The design storm event criteria associated with the various features, and guidance on storm water analysis and design, are presented in Chapter 5 of Volume 2.

After the initial set of on-site controls are selected for the design storms, the full development build-out 100-year, 24-hour storm (or appropriate duration for intensity-based runoff estimates) shall be applied to the on-site conveyance system and storm water controls to determine the overall flow paths, velocities and depths for the larger storm. Even though the conveyance systems may be appropriately designed for smaller design storm events per the criteria discussed in Chapter 5, overall the site must be designed to safely pass or temporarily store the resulting flows from the full build-out 100-year storm event without flooding structures or other critical features. Refer to the storm water ordinance and Chapter 5.

Refer to Chapter 4 of Volume 2 for a description of the methods used to compute peak flows for use in the on-site conveyance design. Typically, for small sites, the Rational method is used for on-site infrastructure design unless peak flow control detention facilities are located within the interior of the site (i.e., not just at the project boundaries). In the latter case, hydrograph methods would be applicable.

1.2.5 Flood Control

Principal and emergency storm water controls must be designed to ensure that the post-development peak discharges for the 2-year through 100-year, 24-hour rainfall events do not exceed pre-development values at the project boundary, and can be discharged safely from the project. (See the storm water ordinance for limited exceptions to this requirement.) This is typically accomplished by constructing a storm water detention pond at or near the downstream project boundary that is designed to control peak flows, and is constructed in such a manner that will permit the flood discharges to pass through and beyond the facility without causing damage to the facility or receiving stream.

The physical characteristics required for detention ponds are reviewed in Chapter 3 of Volume 2. The hydrologic procedures for computing flood inflow to detention ponds, and routing those flows through the ponds, are presented in Chapter 4. Note that when multiple flood control facilities are located within the site (not just at the project boundaries), a hydrologic model reflecting the pond network must be used. A discussion of hydraulic analysis and design for energy dissipators/erosion protection, spillways, channels, etc. is presented in Chapter 5.

1.2.6 Downstream Assessment

In conjunction with the basic flood control requirements (above), principal and emergency storm water controls must be designed to ensure that the post-development peak discharges for the 2-year through 100-year, 24-hour rainfall events do not exceed pre-development values downstream of the project boundary. (See the storm water ordinance for limited exceptions to this requirement.)

The downstream assessment is the process for determining if the development will increase flooding or erosive velocities at downstream locations. This assessment is to be conducted from the project boundary downstream to the point where the discharge from the proposed development no longer has a significant impact on the receiving stream or storm drainage system.

The detailed procedures for conducting the downstream assessment are provided in Chapter 4 of Volume 2. In general, the assessment includes:

- <u>Determining the Zone of Influence</u>: This is the section of stream downstream of the project that experiences increased peak flows or velocities due to the development. For off-line projects (detention ponds not located on the main receiving stream), the zone of influence is assumed to extend no further downstream than the point at which the project drainage area is equal to 10% of the total watershed area at that location. For on-line detention ponds (ponds located on the main receiving channel), the zone of influence is the 10% point described above, or the location where the post-development flows and velocities no longer exceed the pre-development values, whichever location is further downstream.
- <u>Modeling</u>: Prepare hydrologic models for the project basin and the receiving stream watershed for pre- and post-development conditions, and compute the peak flows and velocities at locations specified in the criteria.
- <u>Revise Management Facilities</u>: Compare pre- and post-development peak flows and velocities, and revise the facility design as necessary to achieve acceptable results.

1.2.7 Summary of Integrated Site Design Requirements

In summary, the following are required (unless accepted in limited cases under the provisions of the storm water ordinance):

- The runoff from the entire development area (except as adjusted for WQ_v reductions) must be treated to remove at least 80% of TSS for the 85th percentile rainfall of 1.2 inches. (Water Quality.)
- The runoff from the entire site (including WQ_v reduction areas) for the 1-year, 24-hour storm event must either be detained for at least 24-hours, or the difference in pre- and post-development runoff volume for that event must be retained on-site. (Channel Protection.)
- On-site storm water conveyances must be designed to convey the peak flows associated with their applicable design rainfall criteria, and must also be capable of conveying the 100-year event without flooding structures or other critical features. (On-Site Conveyances.)
- If the project results in an increase in flood peaks at the project boundaries, detention controls must be provided to ensure that post-development flows do not exceed pre-development peak flows at the project boundaries, and that the flows may be safely passed through the detention facilities. (Flood Control.)
- Flow conditions in the receiving stream downstream of the project must be evaluated to ensure that the development does not increase peak flows or velocities. (Downstream Assessment.)

1.3 Preferred Site Design and WQ_v Reductions

The ISD requirements discussed in Section 1.2 are driven by the hydrology of the development site. In the most basic sense, the more runoff generated by a site, the greater the amount of WQ_v that must be treated, the larger the amount of CP_v that must be managed, and the larger the peak flows that must be attenuated for flood control. Therefore, there is a built-in incentive for a development to be designed in a manner that would result in less runoff volume and lower peak flows than would a conventional design that does not consider those effects. This approach is called “Preferred Site Design” (PSD). These “non-structural” practices are not required, but are recommended where practicable and economically viable.

PSD practices are discussed in detail in Chapter 2 of Volume 2. In general, these practices consist of site designs that minimize impervious areas, minimize disturbance of site soils, preserve natural areas, and promote infiltration (where permissible). The obvious effect is reduced hydrologic response of the development and a reduction in the amount of pollutants and thus required treatment. However, the benefits of these practices must be weighed against the economics of developing the site. Therefore, the practices are not required.

Some of the PSD practices are sufficiently effective at reducing or eliminating pollutants in runoff that they are designated as WQ_v reductions. Runoff from those areas is not required to be treated for water quality protection and thus may be subtracted from the WQ_v. Reductions are discussed in detail in Chapter 2 of Volume 2.

1.4 Structural Storm Water Controls

In some cases, the use of non-structural PSD practices may eliminate the need for constructing any storm water management facilities (storm water controls) on a site other than for routine conveyance needs. However, in most cases structural storm water controls must be used to completely accomplish all of the requirements of integrated site design.

Chapter 3 of Volume 2 provides a detailed presentation of the various types of storm water management facilities permitted for use. In general the controls consist of detention, filtration, or infiltration facilities that remove TSS from the runoff, and/or detain runoff for quantity control (CP_v and floods). Examples include detention and retention ponds, constructed wetlands, bioretention areas, infiltration trenches, and engineered swales. For each type of control, a design value for the TSS removal rate is provided for use in computing overall TSS removal for the project site. In addition, specific criteria for the facilities are provided to ensure that the control will achieve the design objectives.

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